**SCRUBBER**

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention regards separation of liquid from gas. In particular, the present invention regards a scrubber with beneficial properties.

2. Description of the Related Art

A number of known installations function to separate fluids of different density by use of a cyclone principle. The principle works by the deflection of a compounded fluid flow for example along the inner wall of a vessel, whereby the heavier constituents move to the outside of the curved fluid flow and are accumulated towards the inner wall of the vessel, after which the heavier constituents as a result of gravitation can be directed to a reservoir or outlet in the bottom of the vessel. The lighter constituents will be concentrated in the center area of the vessel, after which they can be taken out through an outlet beginning in the center area of the vessel.

Some examples of cyclones that can be used for separation of fluids of different density can be found in patent publications NO 308199 and NO 144128, which regard hydrocyclones. The publications teach separation of fluids in the form of liquids, or even liquids with contents of solid constituents, which are fluids of relatively high viscosity. For fluids of high viscosity it is essential to avoid unnecessary pressure loss, which problem is described in the publications.

Pressure loss is also an essential problem with respect to separation of liquids and/or particles from a fluid flow that in substance comprises gas. This is described in patent publication NO 176309, which discloses a device for separation of liquid and/or particles from a high pressure gas flow. In this publication, on page 1, lines 32-38, it is set forth: "*The gas density is a very important parameter with respect to the efficiency of a centrifugal gas separator. In general the collection efficiency and also the pressure loss of a centrifugal separator achieve the most preferable values when the flow through the separator is an ideally arranged centrifugal flow on which no other flow such as turbulence and secondary flows have influence.* "

The device according to NO 176309 comprises a cylindrical vessel with an in substance vertical axis, equipped with: an upper compartment to which gas is fed; an intermediate

compartment comprising a number of vanes that are arranged in spiral around the axis; a lower compartment for separation of gas and liquid and/or particles and a coaxial gas outlet pipe extending upwards from the lower compartment through the intermediate compartment and upper compartment, around which spiral formed vanes have been provided; which device is distinguished in that each spiral formed vane is comprising a lower part with a constant slope and a part with a slope that increases gradually in upward direction.

The vanes of the above mentioned device bring the gas into rotation, and the vanes are arranged on the coaxially arranged gas outlet pipe.

In patent publication GB 1119699 an inlet is described that is directed downwards, in contrast to the conventional vane inlet (Schepentoeter) that is directed outwards. The inlets are significant for how the flow is distributed into the scrubber.

Despite devices as those mentioned above, a demand still exists for improvements, in particular with respect to a device that in agreement with the above has most beneficial properties when the flow through the separator is an ideally arranged centrifugal flow on which no other flow such as turbulence and secondary flows have influence. The objective of the present invention is to provide a device that is contributing to meet the above mentioned demand.

## SUMMARY OF THE INVENTION

With the present invention a scrubber is provided for separation of liquid phase and any other constituents from a fluid flow that in substance comprises gas. The scrubber is formed as a standing vessel with a round cross-section, with an outlet for liquid from the bottom and an outlet for gas from the top.

The scrubber is distinguished in that it comprises:

a fluid inlet that either is tangentially oriented to the inner wall of the scrubber or equipped with a deflection plate, such that introduced fluid is directed tangentially horizontal or with a small downward slope along the inner wall of the scrubber, into and through a fluid way arranged as a downwards directed spiral within the scrubber, along the inner wall, from a level over or at the inlet to a level at or close to the outlet for liquid, with an opening for permitting gas to escape inwards to the center of the scrubber.

The language "a vertical standing vessel" is intended to mean a vessel with the longitudinal axis oriented vertical or at a small angle from vertical. The language "round cross-section" is intended to mean a vessel with a cross-section that is circular or close to circular, for example elliptical or with other deviation from circular. The language "along the inner wall of the scrubber" is intended to mean on the inner wall of the scrubber or a small distance from the inner wall of the scrubber.

The fluid ways are preferably arranged coaxial with the longitudinal axis of the scrubber.

With the scrubber according to the invention introduced fluid will be passed in a downwards directed spiral course in the fluid way within the scrubber.

With the present invention a device is provided, which in operation to a great extent provides an ideally arranged centrifugal flow on which no other flows such as turbulence and secondary flows have influence. This is achieved in that all fluid deflection can take place on the inner wall of the scrubber and in that the fluid way in substantial degree is providing a shielded laminar flow on which other fluid flows such as turbulence and secondary flows have little influence.

With the scrubber of the invention a good separation of liquid from gas is achieved by rotation/gravitation with minimum generation of turbulence and minimum entrainment of droplets. Further, the accumulation of upstream coalesced liquid is passed relatively unaffected of the gas flow down to the bottom section. The inlet and the fluid way according to the invention are robust with respect to variations in liquid fraction in the feed flow, and result in reduced liquid fraction in the feed to downstream located liquid separation equipment. The result is a good primary liquid separation, with 50 to 75% reduced liquid contents in the gas downstream of the fluid way compared to conventional inlets. The operation of optional devices in the top and bottom of the scrubber, to reduce the liquid ratio further, also becomes more effective.

## BRIEF DESCRIPTION OF THE DRAWINGS

The invention is illustrated in the accompanying drawings, more specifically:

Figure 1 illustrates an embodiment of the scrubber according to the present invention, more specific the distinguishing parts thereof; and

Figure 2 and Figure 3 present experimental data in a graphical form.

## DETAILED DESCRIPTION OF THE INVENTION

With reference to Figure 1, a typical embodiment of the distinguishing features of the scrubber according to the present invention is illustrated, more specifically a fluid inlet and a fluid way. The inlet 1 directs the fluid flow towards a deflection plate 2 which again directs the fluid flow into a fluid way 3. The fluid way consists of a guiding plate 4 and an upwardly extending edge 5 fastened along the inner edge of the guiding plate towards the center of the scrubber.

The scrubber according to the invention preferably comprises a fluid way in the form of a guiding plate that is fastened on the inner wall of the scrubber in spiral form from a level above the inlet to a level just above the outlet for liquid. The guiding plate extends out towards the center axis of the scrubber a distance from 5% to 20% of the inner diameter of the scrubber and is equipped with an upwards extending edge of height 75-150% of the width of the guiding plate closest towards the center of the scrubber.

The width of the fluid way preferably covers 5-20% of the inner diameter, because a larger coverage results in higher local vertical gas velocities, with an increased tendency to entrainment of droplets, while a lower coverage results in lower capacity. The limits can be exceeded, but according to the above do not represent preferred embodiments.

The upwards extending edge is preferably parallel to a virtual coaxially arranged cylinder within the scrubber and functions to collect and direct liquid downwards into the scrubber and to hinder or minimize entrainment of liquid upwards in the scrubber with the gas flow.

The inlet can preferably be tangential and with the same slope as the fluid way, whereby it can be achieved that all fluid deflection can take place against the inner wall of the scrubber or fluid way.

In a preferred embodiment of the scrubber according to the invention, the fluid way is a guiding plate that on the inner wall of the scrubber is fastened in spiral form 1-2 revolutions from the top of the scrubber somewhat above a centered inlet with a deflection plate to a level somewhat above the liquid phase in the bottom of the scrubber. The guiding plate has uniform slope and extends 10% of the inner diameter of the scrubber from the wall and is equipped with a middle adjusted fastened upwards extending edge with a height that is equal to the width of the guiding plate closest towards the center of the scrubber.

The spiral has preferably 1-2 revolutions to limit the height of the scrubber, but with respect to effect more revolutions can be provided. The slope of the spiral is typically 10 % downwards from the horizontal, but the slope can be varied. For a typical scrubber with an inner diameter of 400 mm, a typical vertical height between each spiral revolution will be 150 mm.

The fluid way preferably comprises a spiral formed pipe placed within the scrubber. The spiral formed pipe in the top of the scrubber is oriented in direct elongation from a tangential inlet and extends to just above the outlet in the bottom of the scrubber, and the spiral formed pipe in all its length has a longitudinal or several closely spaced openings for gas escape. This embodiment is in particular preferable with respect to fabrication.

The scrubber can preferably be formed as a truncated opposite cone where a spiral formed fluid way in the form of a longitudinally open pipe with spiral wound adapted to the form of the scrubber has been introduced. Thereby a gradually increasing deflection of the fluid flow is achieved, and thereby a gradually increasing liquid separation is realized.

A vortex breaker is preferably arranged above the outlet of the scrubber. Thereby liquid can flow freely from the vortex breaker down to the liquid that is to be kept in the bottom of the scrubber, while gas can rise upwards to the gas outlet in the top of the scrubber. The vortex breaker can have different known designs, of which two examples are guiding plates breaking the spiral flow and a so called China hat, respectively.

The fluid way can in downward direction preferably have an increasing slope. Thereby, an increasing ratio of liquid can more easily be directed downwards to the bottom of the scrubber.

The fluid way can, in the downward direction, have an increasing opening for gas escape. This can be preferable for achieving a high liquid ratio in the fluid flow at the bottom of the fluid way and to avoid that gas already being relatively dry is mixed with liquid in an optional vortex breaker and therefore is entraining liquid.

The scrubber according to the present invention can have more embodiments than the above mentioned. For example the number of rotations in the fluid way can be significantly larger than two, for example five or at maximum as many as still provide liquid separation. The scrubber can further, for example, be designed as a spiral in a downwards directed pipe, around which spiral a vessel is constructed with an outlet for gas in the top and an outlet for liquid in the bottom. The scrubber can contain more equipment than mentioned above. For example equipment for demisting can be arranged in the top of the scrubber, such as thread grids (mesh), cyclones and/or vanes, which can be of known types or of new types. The fluid way is arranged between optional equipment for demisting in the top of the scrubber and optional equipment for vortex breaking in the bottom of the scrubber. Further equipment in the scrubber according to the invention may comprise, for example, instrumentation.

Particularly preferable, the scrubber has a fluid way that is completely closed for gas escape at the upper end at the inlet, but is gradually opened for escape of gas towards the outlet, and the fluid way has about five revolutions in total, which embodiment appears to be the most preferred one in general because of lowest remaining demand for demisting.

An experiment was conducted with a feed consisting of air and water. Over the inlet a thread grid (mesh) was placed in a distance 600 mm from the inlet. Two types of scrubbers were used, namely one with an inlet and fluid way according to the present invention and one with the conventional vane inlet of the prior art construction. The scrubbers were identical in other respects. The results of the experiment are given in the graphical illustrations of Figures 2 and 3, respectively. GLF represents gas load factor = v · (density gas/density liquid - density gas). As can be seen from the illustrations, a significantly lower liquid entrainment resulted with the scrubber according to the present invention compared to the scrubber with the prior art vane inlet. The scrubber with the inlet and fluid way according to the present invention resulted in about 50 to 75% reduced liquid ratio downstream of the fluid way.